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BIDIRECTIONAL METER USED FOR VOLUMETRIC MEASUREMENT OF MILITARY-STANDARD HYDROCARBON LIQUID FUELS AT BULK STORAGE INSTALLATIONS

by

Joe Medrano

February 1972

U. S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER
FORT BELVOIR, VIRGINIA

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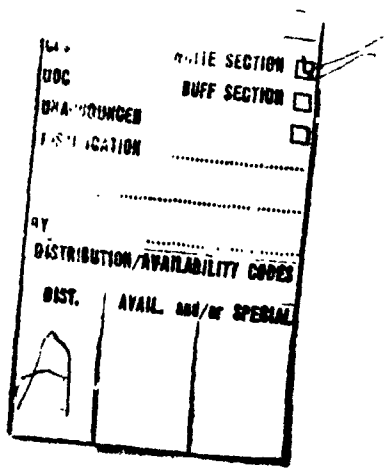

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This report covers the testing and evaluation of a bidirectional vortex velocity meter to determine its suitability for volumetric measurement of liquid hydrocarbon fuels in conjunction with the operation of 10,000- and 25,000-barrel hasty storage reservoirs.

A Rotron, 4-in., vortex-velocity meter with a range of flow from 200- to 1250-gpm was installed at USAMERDC test facilities and fuel was pumped through the meter in forward and reverse directions of flow to determine the accuracy. The overall accuracy obtained was within the desired ± 1-percent limit with a repeatability of ± 0.1 percent of meter readings when operating within the meter linear range.

Details of illustrations in this document may be better studied on microfiche

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BIDIRECTIONAL METER USED FOR VOLUMETRIC MEASUREMENT OF MILITARY-STANDARD HYDROCARBON LIQUID FUELS AT BULK STORAGE INSTALLATIONS

Task 1J664717DL4111

February 1972

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SUMMARY

This report covers the testing and evaluation of a bidirectional vortex-velocity meter to determine its suitability for volumetric measurement of liquid hydrocarbon fuel in conjunction with the operation of 10,000- and 25,000-barrel hasty-storage reservoirs.

A Rotron, 4-in., vortex-velocity meter with a range of flow from 200 to 1250 gpm was installed at USAMERDC Test Facility, and fuel was pumped through the meter in forward and reverse directions of flow to determine its accuracy. The overall accuracy obtained was within the desired ± 1-percent limit with a repeatability of ± 0.1 percent of meter readings when operating within the meter's linear range.

FOREWORD

The testing and evaluation covered by this report was conducted under the general authority of Project 1J664717DL41, POL Distribution Systems. The work was accomplished in conformance with specific requirements of Task 1J664717DL4111, Bulk Fuel Storage.

The period covered is March 1968 through May 1969.

This project was under the general supervision of John D. Grabski, Chief, Fuels Handling Equipment Division, and under the direct supervision of N. A. Caspero, Chief, Onshore Fuel Systems Branch.

The following personnel participated in the test program: James Christopher, Equipment Specialist; Warren Parrish, Test Leadman; Richard Clement and Robert Casteel, Test Mechanics.

CONTENTS

Section	Title	Page
	SUMMARY	ii
	FOREWORD	iii
	ILLUSTRATIONS	v
	TABLE	v
I	INTRODUCTION	
	1. Subject	1
	2. Operational Requirement	1
II	INVESTIGATION	
	3. Type of Meter Investigated	1
	4. Description of Meter	2
	5. Description of Test	3
	6. Results of Tests	3
III	DISCUSSION AND EVALUATION	
	7. Analysis of Deficiencies	7
	8. Evaluation of Equipment	12
IV	CONCLUSIONS	
	9. Conclusions	12
	APPENDIX – Purchase Description	13

ILLUSTRATIONS

Figure	Title	Page
1	Meter Flow Pattern	2
2	Test Arrangement at USAMERDC Test Facilities, Showing Pipe Layout with Flowmeter in Position	4
3	Test Arrangement at USAMERDC Test Facilities, Showing Flowmeter and Test Monometer	5
4	A 4-In. and 3-In. Meter Calibration Test Setup	6
5	Calibration Curves of 4-In. Flowmeter Obtained with Proving Tank	8
6	Calibration Curves of 3-In. and 4-In. Flowmeters Obtained with Proving Tank	9
7	A 6-In. Vortex-Velocity Meter	10
8	Flowmeter Assembly	11

TABLE

Title	Page
Sizes of Rotron Bidirectional Flowmeters	12

BIDIRECTIONAL METER USED FOR VOLUMETRIC MEASUREMENT OF MILITARY-STANDARD HYDROCARBON LIQUID FUELS AT BULK STORAGE INSTALLATIONS

I. INTRODUCTION

1. Subject. This report describes the testing and evaluation of a bidirectional-type flowmeter used for volumetric measurements of military-standard hydrocarbon liquid fuels at bulk storage tank installations.

2. Operational Requirement. A requirement exists for a volumetric measuring meter which would be suitable for operation in the 8-in. pipeline used to fill and drain fuel from the 10,000-barrel and 25,000-barrel hasty-fuel-storage reservoirs. The meter is to be capable of operating satisfactorily in normal and reverse directions of flow when installed in the pipeline, without requiring bypassing or looping, or without requiring change of meter parts or reversal of the meter in the pipeline. Since the hasty-fuel-storage reservoirs are installed in earthen pits, each having different nonuniform dimensions, the quantity of fuel in the reservoirs is difficult to determine by conventional methods of gaging, and a meter is necessary to keep an accurate account.

II. INVESTIGATION

3. Type of Meter Investigated. The most suitable meter for Army field use would be a flowmeter (i.e., positive displacement, turbine, electromagnetic, orifice, etc.) meeting the following requirements, some of which are described more fully in the appendix to this report:

a. Linear rangeability.
b. Repeatability.
c. Meter reproducibility.
d. Insensitivity to viscosity.
e. Meter factor adjustment.
f. Meter factor consistency.
g. Compatibility to fluid.
h. Life of moving parts.
i. Readout restrictions.
j. Ease of maintenance.

With these features in mind, a vortex meter was selected and evaluated at the U. S. Army Mobility Equipment Research and Development Center (USAMERDC)

at Fort Belvoir, Virginia, to determine its suitability for volumetric measurement of fuel. The meter tested was a Rotron, 4-in., vortex-velocity meter, Model No. L4C, 200- to 1250-gpm nominal flow range extended to 1560 gpm, from Rotron Controls Division, Rotron Manufacturing Company, Inc., Woodstock, New York (Ed. Note: Now Dresser Measurement Division; Dresser Industries, Inc.; Houston, Texas 77001.)

4. **Description of Meter.** The flowmeter design utilizes the patented Rotron Vortex-Velocity Principle wherein the rotor speed responds linearly to the velocity of the liquid flow through the meter body (Fig. 1). Direct mechanical readout is provided by means of a magnetic coupling, requiring no stuffing boxes or packing blands.

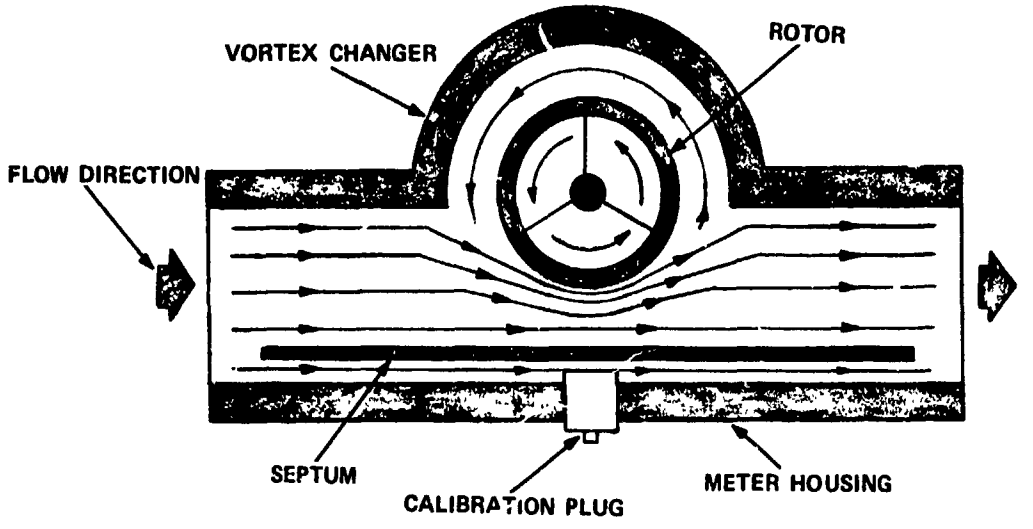

Fig. 1. Meter Flow Pattern.

Two factors set the Rotron flowmeter apart from other meters. First, the sensing rotor does not measure the full cross section of flow. The rotor extends part way into the fluid which allows for large clearance and a convenient method of meter factor adjustment. Large clearance between rotor and meter housing is desirable to allow for the passage of foreign particles that may be mixed with the fuel. Second, the rotor blades are not synchronous with respect to main stream velocity. Synchronization is common throughout the turbine meter industry, and the slightest drag torques will adversely affect the meter's performance.

When the new bidirectional requirement was presented to manufacturers at the time bids were solicited for engineering-service test models, Rotron expressed an interest in undertaking the development. A design change from unidirectional to

bidirectional flow involved changing the position of the rotor blades and side throttle plates. The Rotron Manufacturing Company claims that the inaccuracy of their bi-directional meter does not exceed ± 1 percent of scale reading for reading accuracy, and ± 0.1 percent for reading repeatability when operating the meter within its linear range. These accuracies can be held over extended periods of time. An increase or decrease in registration can easily be made in the field with a simple screwdriver or wrench adjustment.

Lubrication is not necessary since the partially sealed ball bearings have Teflon-coated balls. Because the meter can be operated in any position, it is imperative that the bottom bearing on the vertical rotor shaft be purged during maintenance of any silt, sand, rust, etc., that may collect around the bearing. A unique feature of the Rotron meter is that the meter does not have to be removed from the line to change parts. The weight of the meter is approximately 125 lb.

The mechanical readout device of the meter is driven by a magnetic coupling. The magnets are the ceramic, permanent type. The directly mounted mechanical totalizer has two counters, one which accumulates (i.e., adds input and subtracts output), and one that can be reset to zero which adds output.

5. **Description of Test.** The 4-in. Rotron meter was installed at USAMERDC Fuels Handling Equipment Test Facility, and fuel motor gasoline from a 2000-gallon proving tank was metered at flow rates of 200, 400, 600, 800, and 1000-gpm. Figures 2 and 3 show the test setup at USAMERDC test facilities. The fuel was pumped through the meter in the forward and reverse directions of flow to determine the percentage of error of the meter. Flow straighteners were used immediately at the inlet of the meter to eliminate swirling of the fuel within the pipe. The 4-in. meter was also installed in series with a 3-in. Rotron meter to compare the percentage of meter accuracy. Figure 4 shows the 4-in.-meter and 3-in.-meter calibration test setup. The 3-in. Rotron meter was also tested in forward and reverse flow rate conditions to obtain a comparison with the 4-in.-meter test results.

The 4-in. meter was also installed and tested in a 6-in. pumping system of a 10,000-barrel hasty-storage reservoir at USAMERDC test facilities to determine the percentage of meter accuracy.

6. **Results of Tests.** The accuracy of the 4-in. Rotron flowmeter tested in the USAMERDC Fuels Handling Equipment Test Facility meter proving system did not agree with the manufacturer's original calibration curve. The manufacturer's data indicated that the errror of the meter did not exceed a 1 percent low count with a reverse direction of flow. The repeatable accuracies of the meter were within the ± 0.1 percent of readings when operating within the linear range but the percentage of error in the

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Fig. 2. Test arrangement at USAMERDC test facilities, showing pipe layout with flowmeter in position.

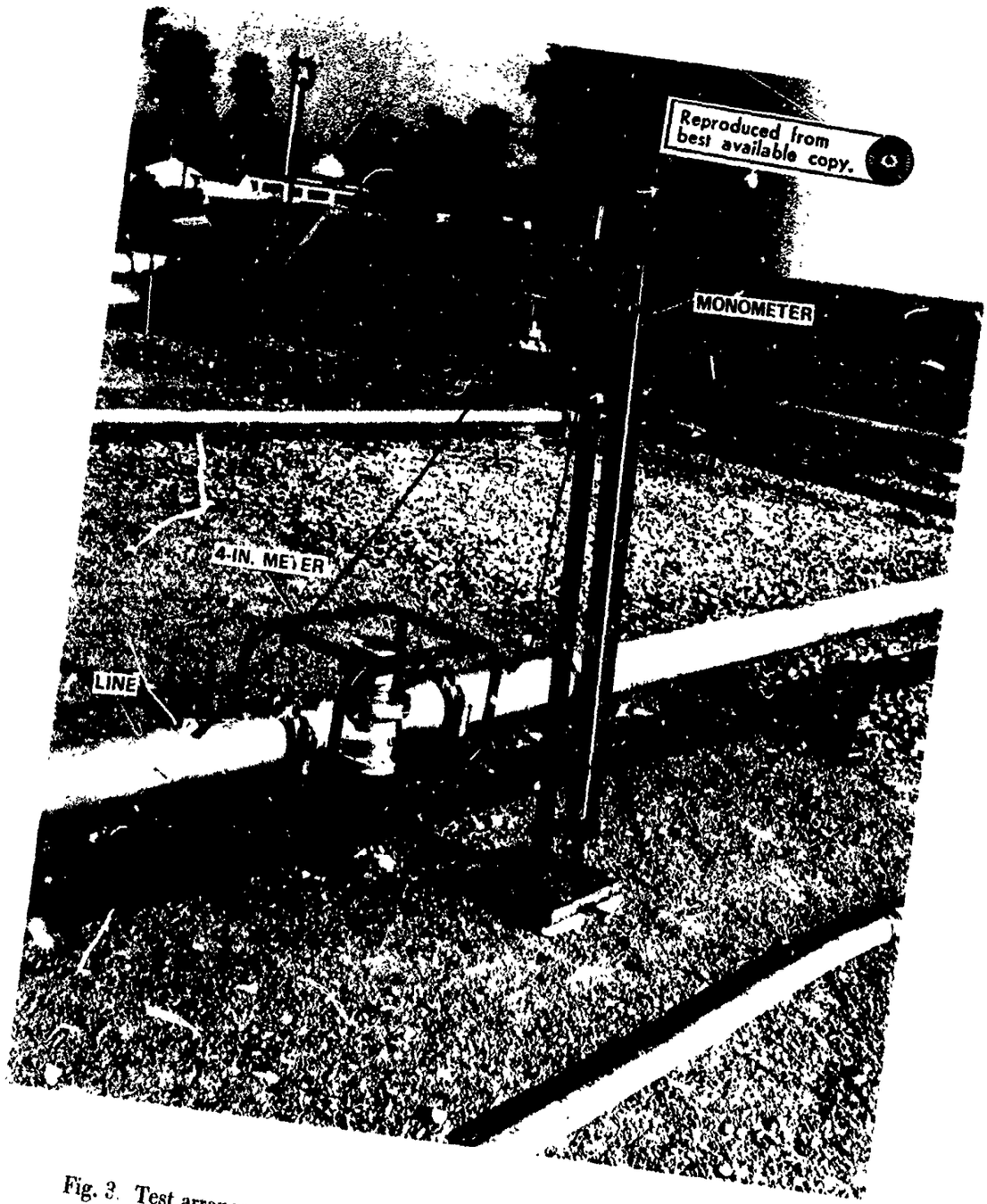
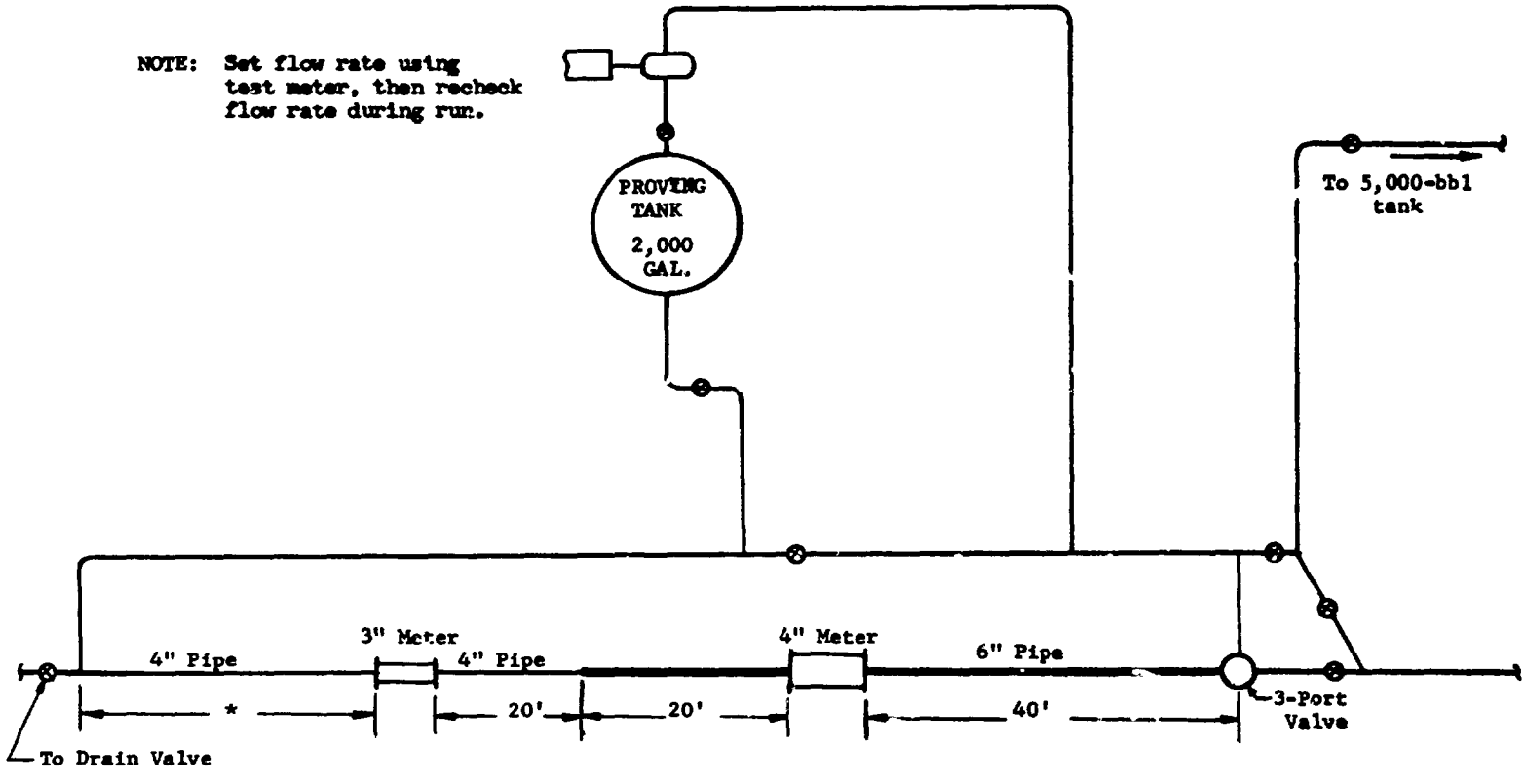


Fig. 3. Test arrangement at USAMERDC test facilities, showing flowmeter and test monometer. P5823



* As much line as possible

Fig. 4. A 4-in. and 3-in. meter calibration test setup.

meter readout at different flow rates when compared to the volume in the USAMERDC-system proving tank was as follows:

a. **Forward Direction of Flow.** The results of this test (Fig. 5) indicated a low meter accuracy of 0.2-percent error at 200 gpm, changing to a high meter accuracy of a 1.1-percent error at 400 gpm, a 1.1-percent error at 600 gpm, and a 0.5-percent error at 1000 gpm.

b. **Reverse Direction of Flow.** The results of this test (Fig. 5) indicated a low meter accuracy of 1.5-percent error at 200 gpm, a 0.4-percent error at 400 gpm, a 0.7-percent error at 600 gpm, and a 1.8-percent error at 1000 gpm.

When curves of the forward and reverse directions of flow of the 3-in. and 4-in. flowmeters were plotted (Fig. 6), a maximum difference of 2.3 percent between respective meter readings was observed. Because of this high percentage of error in the meter readout, the meter was returned to the Rotron Manufacturing Company for inspection and further proving. An inspection of the meter at the Rotron plant indicated that the meter was in good condition after USAMERDC calibration tests. The meter was then installed in the Rotron meter-proving system, and a series of tests was conducted. The test results differ from those conducted at USAMERDC facilities because of the difference in flow patterns and piping arrangements of the respective systems.

With the 4-in. Rotron meter installed in the 6-in. pumping system of the hasty-storage-reservoir test area, 600,382 gallons of fuel were pumped out of the reservoir. The following day, 529,328 gallons of fuel were pumped back into the hasty-storage reservoir, making a total of 1,129,710 gallons metered by the Rotron meter in the cycle. A comparison between the quantity of fuel pumped and fuel metered indicated an average of 4904 gallons of fuel metered by the Rotron meter amounting to 0.43 percent overage of meter reading.

III. DISCUSSION AND EVALUATION

7. **Analysis of Deficiencies.** From the tests conducted, it was determined that the measurability of the meter was affected by different flow patterns of the fuel passing through the meter, and that the flow pattern in one system will normally be different from the flow pattern in any other system because of the design of the pumps employed, different design and layout of piping, and other factors. Therefore, when the flowmeter is used in any system other than where it was originally calibrated, the accuracy of the meter will be affected.

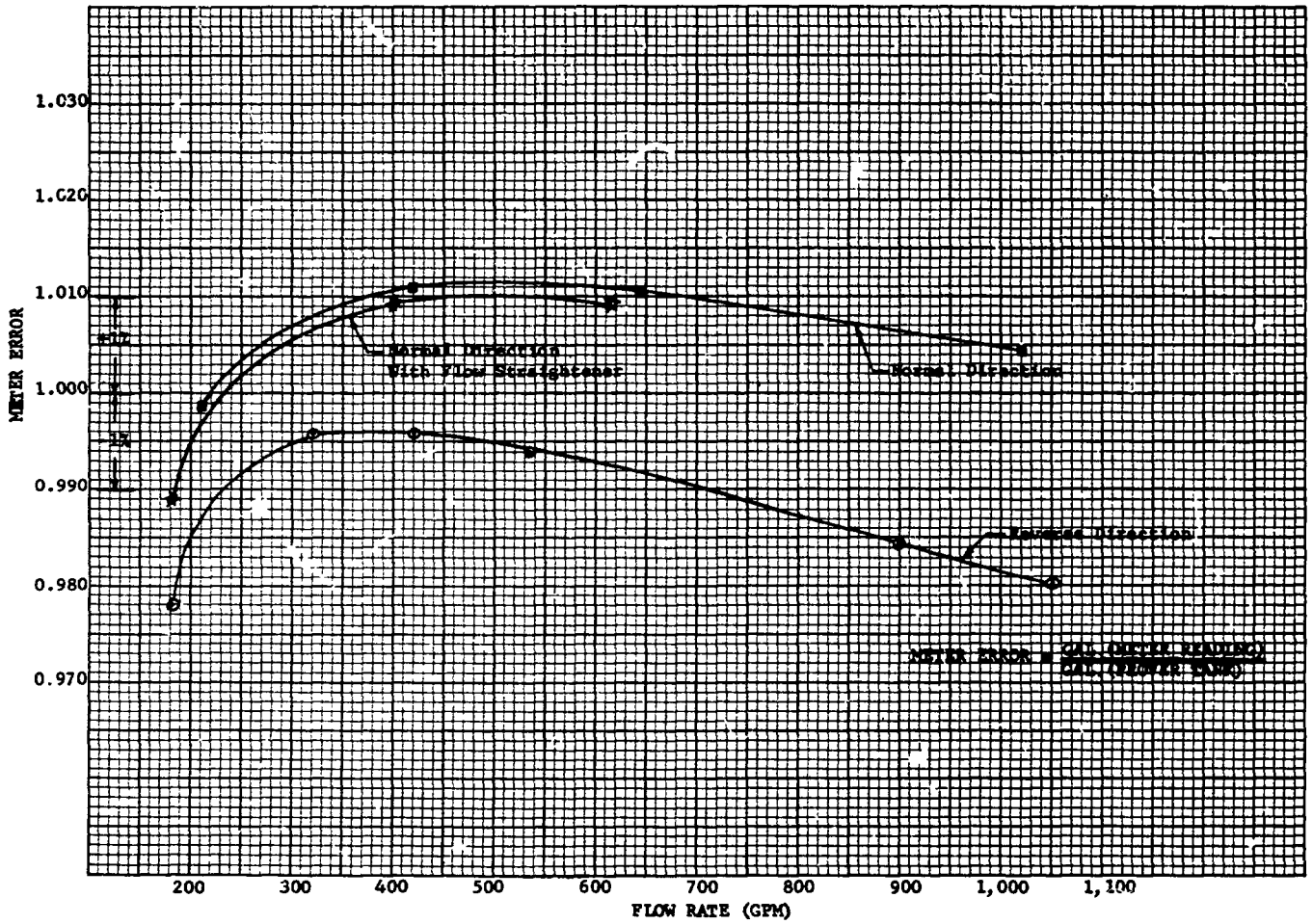


Fig. 5. Calibration curves of 4-in. flowmeter obtained with proving tank.

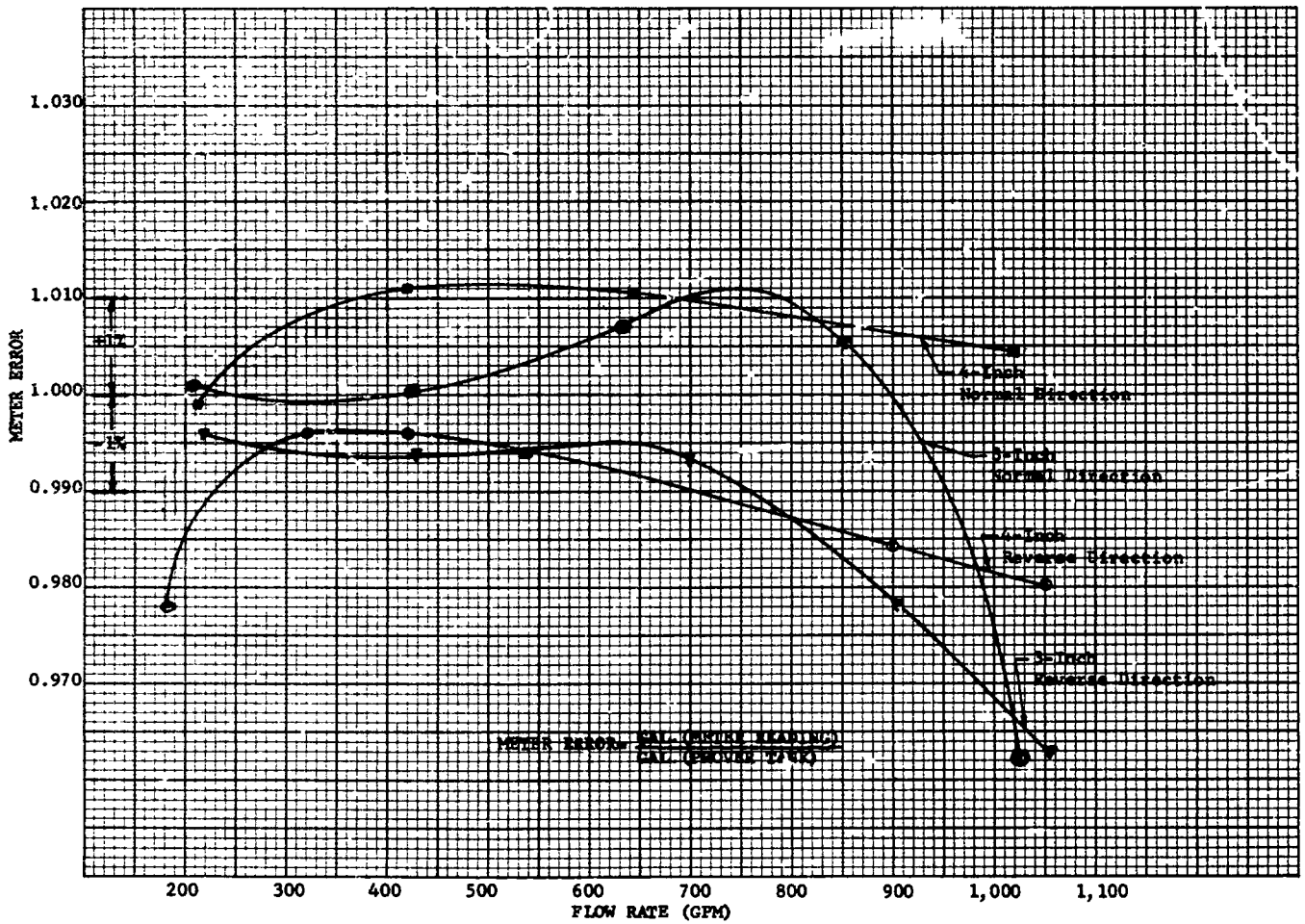


Fig. 6. Calibration curves of 3-in. and 4-in. flowmeters obtained with proving tank.

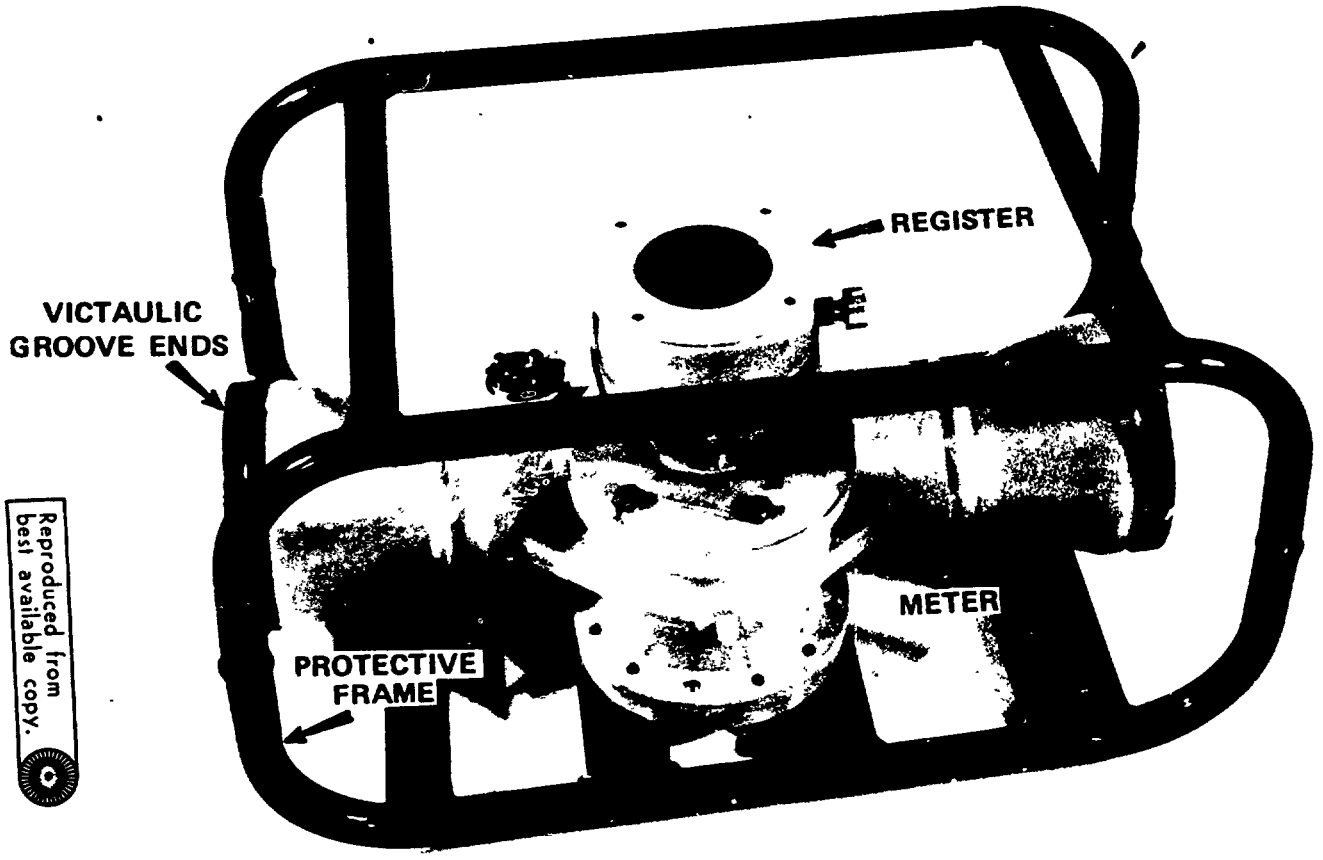


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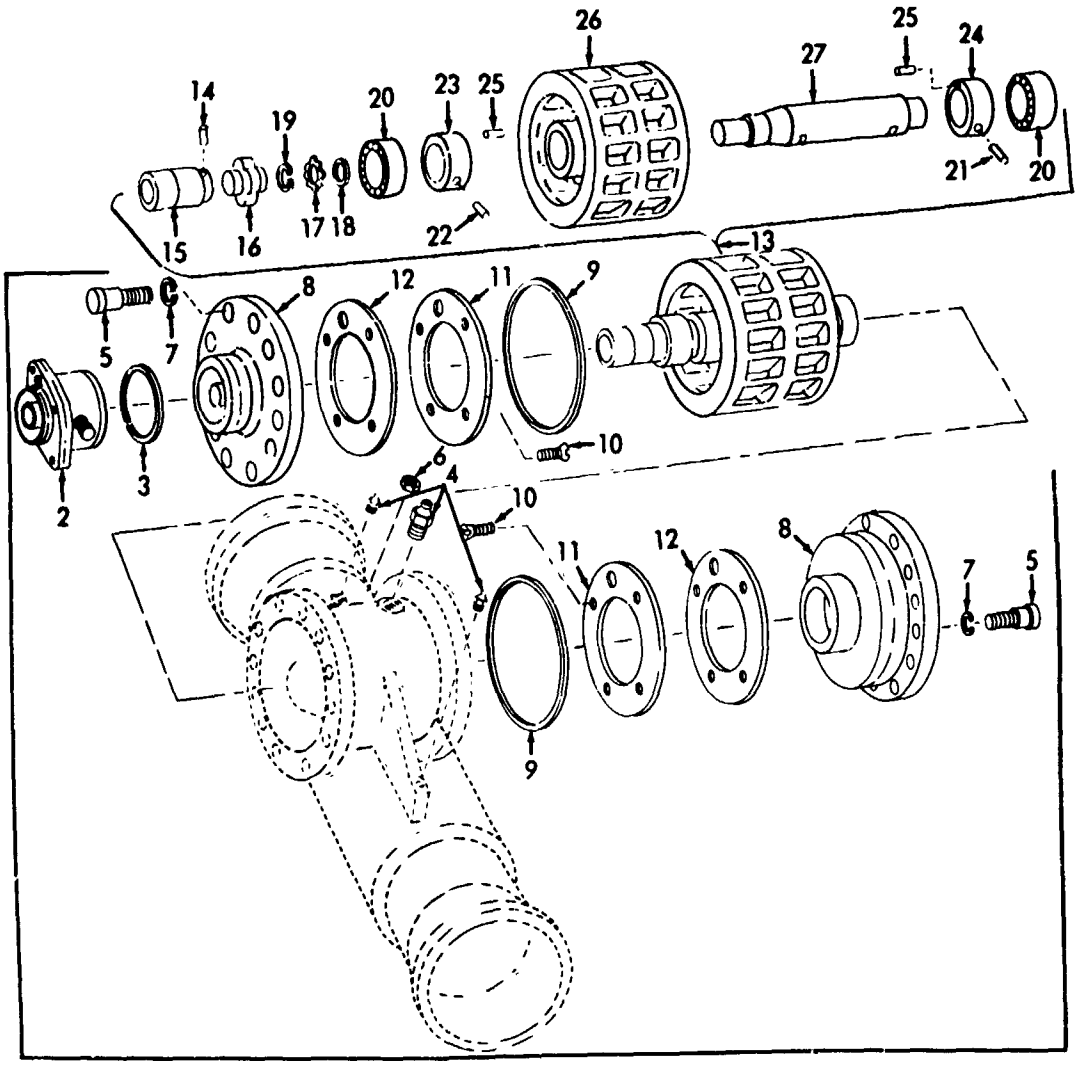
Fig. 7. A 6-in. vortex-velocity meter.



NOTE: 6-INCH METER SHOWN, PROCEDURES FOR 8-INCH METER ARE SIMILAR.

1. METER ASSY	10. SCREW	19. WASHER
2. REGISTER ASSY	11. PLATE	20. BEARING
3. GASKET	12. SPACER	21. PIN
4. PLUG	13. ROTOR ASSY	22. SCREW
5. SCREW	14. PIN	23. COLLAR
6. NUT	15. MAGNET	24. COLLAR
7. WASHER	16. NUT	25. PIN
8. COVER	17. WASHER	26. ROTOR
9. GASKET	18. WASHER	27. SHAFT

Fig. 8. Flowmeter assembly.

During days of high humidity, water vapor condensed on the inside of the glass face of the meter-register assembly, making the register difficult to read. A seal-tight register assembly should prevent condensation from forming.

Sizes of Rotron Bidirectional Flowmeters

Line Size (In.)	Meter Body Size (In.)	Flow Rate Range (gpm)	Dimensions (In.)	Weight* (lb)	Body Material
4	3	65 to 800	25 x 14 x 15	55	Aluminum
6	4	125 to 1500	25 x 15 x 14	125	Carbon Steel
8	6	260 to 3600	36 x 22 x 20	300	Carbon Steel

*Weight of meter includes protective frame and victaulic groove end connections.

8. Evaluation of Equipment. The Rotron meter in proper size (see the Table) will provide an excellent instrument for volumetric measurement of fuel at bulk fuel installations. The meter is rugged and simple in design (Fig. 7) and can be repaired easily without drastically affecting the original calibration. Other important features of the meter are its readout simplicity, size, and weight. There are no close clearances within the meter body, so there is no need for strainers or filters. No electrical power is required for the flow register.

New bearings or any other part of the rotor assembly (Fig. 8) can be replaced within a minute. The accuracy of ± 1 percent of the meter is sufficient to keep an accurate account of the large quantity of fuel stored in tank farms. A meter with a greater accuracy will increase in size, weight, and cost.

IV. CONCLUSIONS

9. Conclusions. The Rotron bidirectional vortex-velocity type meter is well adapted for Army field use because of readout simplicity, size, weight, and ease of maintenance. The overall meter accuracy obtained at the USAMERDC Fuels Handling Equipment Test Facility was within the desired ± 1-percent limit with a repeatability of ± 0.1 percent of meter readings when operating within the meter's linear range. The accuracy of this meter is considered sufficient to keep an accurate account of the quantity of liquid fuel in bulk storage installations.

APPENDIX

U. S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER FORT BELVOIR, VIRGINIA

PURCHASE DESCRIPTION FOR METER, VELOCITY-TYPE, TURBINE, FOR HYDROCARBON LIQUID FUELS, 500- TO 2800-GPM NOMINAL FLOW RANGE, 150-PSI WORKING PRESSURE

1. SCOPE

1.1 This purchase description covers a nominal 6-inch-diameter, flow-measuring velocity turbine meter to be used for volumetric measurement of military-standard hydrocarbon liquid fuels at bulk storage installation.

2. APPLICABLE DOCUMENTS

2.1 The following specifications and standards form a part of this purchase description:

SPECIFICATIONS

Federal

VV-F-800	– Fuel Oil, Diesel
PPP-T-60	– Tape, Pressure-Sensitive Adhesive, Waterproof, for Packaging and Sealing
PPP-B-601	– Boxes, Wood, Cleated-Plywood
PPP-B-621	- Boxes, Wood, Nailed and Lock-Corner

Military

MIL-B-121	– Barrier-Material, Greaseproofed, Flexible (Waterproofed)
MIL-G-3056	-- Gasoline, Automotive, Combat

MIL-C-5541	– Chemical Films for Aluminum and Aluminum Alloys
MIL-G-5572	– Gasoline, Aviation: Grades 80/87, 91/96, 100/130, 115/145
MIL-J-5624	– Fuel, Aircraft, Turbine and Jet Engine Grades JP-3, JP-4, and JP-5
MIL-A-8625	– Anodic Coatings for Auminum and Aluminum Alloys
MIL-C-10387	– Coupling, Clamp, Pipe with Bolts and Synthetic-Rubber Gasket For Grooved-End Pipe and Tube
MIL-P-10388	– Pipe Fittings: One or More Ends Grooved
MIL-F-46005	–Fuel Oil, Compression-Ignition, Turbine-Engine

STANDARDS

Military

MIL-STD-129	– Marking for Shipment and Storage
MIL-STD-130	– Identification Marking of U. S. Military Property

(Copies of specifications, standards, and drawings required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

2.2 Other publications. The following documents form a part of this purchase description. Unless otherwise indicated, the issue in effect on date of request for quotation shall apply.

OFFICIAL CLASSIFICATION COMMITTEE

Uniform Freight Classification Rules.

(Application for copies of the above publication should be addressed to the Official Classification Committee, 1 Park Avenue at 33rd Street, New York 16, New York.)

AMERICAN TRUCKING ASSOCIATION

National Motor Freight Classification Rules.

(Application for copies of the above publication should be addressed to the American Trucking Association, 1424 16th Street, N. W., Washington, D. C.)

3. REQUIREMENTS

3.1 Description. The meter shall be of a simple design consisting basically of a rotor mounted in the flow stream which senses the flow velocity accurately over a wide range of flows. The meter shall consist of a housing containing the measuring mechanism described above, a mechanism that automatically compensates for changes in viscosity, and a register with direct-reading counter and totalizer. The weight of the meter without the register shall not exceed 55 pounds and the overall length shall not exceed 15 inches. Nominal meter size shall be 6 inches.

3.2 Design. The meter shall be designed as necessary to meet or exceed the operational and performance requirements specified herein. The meter shall be designed for a working pressure of 150 psi. Extended maximum capacity of the meter shall be not less than 3,500 gpm. The nominal flow range shall be at least 500 gpm to 2800 gpm with ability to maintain linear flow characteristics within the nominal flow range. The design shall be such that overhaul and repair can be accomplished easily in the field with common tools. The meter shall be designed for use in light hydrocarbon liquid fuels. The design shall be such that the entire metering assembly, including flow straighteners and viscosity compensator, is included in one housing. Design shall be such that the rotor element operates with a tungsten carbide sleeve bearing over the rotor shaft.

3.3 Material. Material shall be as specified herein. When not definitely specified, the material shall be of the type and quality necessary for the meter to be entirely suitable for the intended purpose.

3.3.1 Meter Body. (See Amendment 1.) The meter body shall be made of aluminum alloy of sufficient strength and temper to meet the design and performance requirements.

3.3.2 Meter Interior. The interior working parts of the meter shall be stainless steel. Interior trim and other removable parts exposed to the fluid stream shall be made

of nonoxidizing material. Materials which in any way adversely affect the fuel characteristics shall not be used.

3.3.3 Register Cable and Power Cable. In the event that an electrical register is required, the cable required for power supply to the register shall be completely suitable for 110-volt-AC, 60-cycle service. The pulse transmission cable to the register from the meter shall be shielded and suitable for the intended purpose. The cables shall have weatherproof coatings or covers that are resistant to fungus and ozone.

3.3.4 Register. The register case and external trim shall be made of materials that resist corrosion, the action of salt-laden atmospheres, sand, dust, and humidity common to tropical zones.

3.3.4.1 Register Face. The register face shall be made of a transparent, colorless plastic that will not craze or fog when continually contacted by windblown sand, dust, and salt spray. The material shall allow all totalizing digits of the register to be easily readable without causing distortion.

3.3.5 Pipe Reducers and Couplings. The pipe reducers and couplings as specified in 3.6 shall be made of malleable iron.

3.4 Performance

3.4.1 Pressure Drop. The maximum pressure drop between the meter inlet and outlet shall not exceed 5 psi for flows in the nominal flow range.

3.4.2 Error of the Meter. (See Amendment 2.) For any flow rate and calibration setting between 10 and 80 percent of the extended maximum capacity, the error of the meter in normal flow direction or reverse flow direction shall not exceed 1.0 percent of actual quantity delivered. For any flow rate within the nominal flow range, the meter precision shall be repeatable within 0.1 percent.

3.4.3 Excessive Flow. The meter shall not be damaged in any way, nor shall the meter accuracy (as specified in 3.4.2) within the percent of the extended maximum capacity, be affected by short term (5 minutes) emergency operation at 125 percent of the nominal maximum flow capacity.

3.4.4 Viscosity Compensation. Compensation of flow measurements for the viscosity of different fuels, ranging within the limits specified in 3.4.6, shall be provided for automatically in the meter design. The parts required for this purpose shall be contained in the meter body. Viscosity compensation shall be provided for when the flow direction is normal and reversed.

3.4.5 Flow Direction. The meter shall be capable of operating in normal and reverse directions of flow as installed in the pipeline without damage to the meter and without requiring bypassing or looping, or without requiring change of meter parts. The bidirectional flow requirement shall not affect a change in meter accuracy or precision beyond the limits specified in 3.4.2.

3.4.6 Flow Characteristics. The meter shall be capable of handling all military standard hydrocarbon fuels conforming to MIL-J-5624, MIL-G-3056, MIL-G-5572, MIL-F-46005, and Fed Spec VV-F-800 at flow temperatures of from -40° F to +140° F. Viscosity of the different fuels can be expected to range between 0.4 and 25.0 centistokes for the operating temperatures.

3.4.7 Temperature. The meter shall perform at an ambient temperature of -25° F without exhibiting any evidence of rupture or failure. The meter shall not be adversely affected by storage where ground temperatures range from -40° F to +145° F, including conditions where condensation takes place in the form of water or frost.

3.5 End Connections. The ends of the meter body shall be grooved conforming to the dimensions for a nominal 6-inch pipe specified in MIL-C-10387.

3.6 Pipe Reducers and Couplings. The meter assembly shall include the component fittings shown in the following table of materials specified in 3.3.5:

Meter Assembly Fittings

Quantity	Description	Reference Specification
2	Reducer pipe, concentric, 8- by 6-inch, groove-to-groove	MIL-P-10388
2	Coupling, clamp, pipe, 6-inch, for grooved-end pipe with synthetic rubber gasket	MIL-C-10387
2	Coupling, clamp, pipe, 8-inch for grooved-end pipe with synthetic rubber gasket	MIL-C-10387

3.7 Register. (See Amendment 1.) The register shall be either mechanical or electrical and shall be of the direct-reading type. The register shall have an add-subtract input totalizer that will add input and subtract output, thereby always showing the volume of fuel in a storage facility. The register shall also have a reset output totalizer that will add the volume output while that volume is being subtracted from the input volume on the add-subtract nonreset totalizer. The add-subtract input totalizer shall

have a minimum of seven digits and the output totalizer shall have a minimum of five digits. The totalizers shall read in U. S. barrels of 42 gallons each. The smallest unit of indicated delivery shall be 1 barrel. The register shall be hermetically sealed, suitable for weather exposure, and capable of table mounting. The register shall be designed to record flow accurately in normal or reverse directions without damage to internal parts. If an electrical register is used, the register and any related or dependent totalizer components attached to the meter or remotely situated shall be explosion proof. If an electrical register is used, power cable and pulse transmitter cables in lengths of 500 feet each shall be provided.

3.8 Register Face. The register face shall be vapor tight to eliminate condensation of moisture on the inside of the register face.

3.9 Nonrolling Attachments. The underside of the meter body shall have external attachments to prevent the meter from rolling when the meter is not contained in a pipeline or hoseline hookup.

3.10 Lubrication. Where required, all moving meter parts shall be provided with suitable means of lubrication.

3.11 Identification Marking. The meter shall be identified in accordance with Standard, MIL-STD-130.

3.12 Treatment. The exterior surfaces of the meter and interior surfaces exposed to fuel shall be treated in accordance with MIL-C-5541 or MIL-A-8625.

3.13 Workmanship. Workmanship shall be of the highest grade throughout and in accordance with good commercial practice for this type of equipment.

3.14 Interchangeability. All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other, with respect to installation and performance.

3.15 (See Amendment 3.)

4. QUALITY ASSURANCE PROVISIONS

4.1 Examination and Testing Responsibility. Unless otherwise specified, all examinations and tests specified hereinafter shall be performed by the contractor. The contractor shall have available, or arrange for use of, the necessary test facilities. The Government reserves the right to perform any of the inspections set forth herein where

such inspections are deemed necessary to assure that supplies and services conform to prescribed requirements.

4.1.1 Component and Material Inspection. The supplier is responsible for insuring that components and materials used are manufactured, examined, and tested in accordance with referenced specifications and standards.

4.1.2 Acceptance Tests. The following tests shall be conducted using fuel conforming to MIL-J-5624, unless otherwise specified.

4.1.2.1 Excessive Flow. The meter shall be subjected to an intermittent overload test of five, 5-minute periods at 125 percent of the nominal maximum flow capacity. Examine for conformance to 3.4.3.

4.1.2.2 Pressure Drop. Measure the pressure drop at 70^{o} F ± 5^{o} F between inlet and outlet of the meter, after the flow rate has been stabilized at 2800 gpm for conformance to 3.4.1.

4.1.2.3 Calibration. (See Amendment 2.) Pump fuel through the meter into an acceptable proving tank at the maximum nominal flow rate. The accuracy of the meter shall be determined with the original factory calibration of the meter. Upon completion of this initial calibration test, examine for conformance to 3.4.2.

4.1.2.3.1 (See Amendment 2.) With the calibration setting used for conformance to 4.1.2.3 pump fuel through the meter into an acceptable proving tank at flow rates from 350 gpm to 2800 gpm at 200-gpm increments. Determine the maximum error and meter precision at any flow rate over this range for conformance to 3.4.2.

4.1.2.3.2 Test for reverse flow as specified in 4.1.2.3. and 4.1.2.3.1 for normal flow. Determine the maximum error and precision at any flow rate for conformance to 3.4.2.

4.1.2.4 Viscosity Compensation. (See Amendment 2.) Tests specified in 4.1.2.3, 4.1.2.3.1, and 4.1.2.3.2 shall be rerun using a fuel with a viscosity that is at least 10 centistokes different from that used in the above tests. Determine the maximum error and meter precision at any flow rate for conformance to 3.4.2.

4.1.3 Acceptance. The manufacturer shall furnish certification of compliance that the meter meets the requirements and will perform as specified herein.

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AMENDMENT NO. 1 TO PURCHASE DESCRIPTION

Delete paragraph 3.3.1 in its entirety and substitute the following:

3.3.1 Meter Body. The meter body shall be made of aluminum alloy or steel alloy of sufficient strength and temper to meet the design and performance requirements.

That portion of paragraph 3.7 reading, "The add-subtract input totalizer shall have a minimum of seven digits, ..." is hereby changed to read: "The add-subtract input totalizer shall have a minimum of five digits, ..."

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AMENDMENT NO. 2 TO PURCHASE DESCRIPTION

That portion of paragraph 3.4.2 reading, " . . . between 10 and 80 percent of the extended maximum capacity, the error of . . . .", is hereby changed to read, ". . . between 500 gpm and 2800 gpm, the error of . . . ."

That portion of paragraph 4.1.2.3 reading, "Pump fuel through the meter . . . .", is hereby changed to read, "Pump a fuel or liquid having a viscosity equivalent to the specified test fluid through the meter . . . ."

That portion of paragraph 4.1.2.3.1 reading, ". . . for conformance to 4.1.2.3 pump fuel through the meter into an acceptable proving tank at flow rates from 350 gpm to 2800 gpm at 200-gpm increments . . . .", is hereby changed to read, ". . . for conformance to 4.1.2.3, pump fuel or liquid having a viscosity equivalent to the specified test fluid through the meter into an acceptable proving tank at flow rates from 500 gpm to 2800 gpm in increments between 300 gpm and 3500 gpm so that at least eight calibration points in the nominal flow range are obtained."

That portion of paragraph 4.1.2.4 reading, ". . . shall be rerun using a fuel with a viscosity . . . .", is hereby changed to read, ". . . shall be rerun using a fuel or liquid with a viscosity . . . ."

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AMENDMENT NO. 3 TO PURCHASE DESCRIPTION

Add the following Paragraph:

3.15 Protective Frame. The meter shall be provided with a protective frame to prevent possible damage to any body appurtenances. Also, the frame may serve as a means of carriage. The frame shall be designed for attachment to the meter body or body fixtures and shall permit accessibility to meter parts requiring clearance for installation and maintenance. The framing shall not interfere in any way with the installation and connection of the meter in either a 6-inch or 8-inch pipeline, Material shall be lightweight (tubular preferred) and sufficiently durable to resist bending or damage by normal handling. The framing material shall be corrosion-resistant, either inherently or by treatment of the surface.